DOCUMENT RESUME

ED 100 978 95 TM 004 096

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TITLE The Acquisition of Visual Information. Final Report.
SPONS AGENCY Office of Education (DHEW), Washington, D.C. Regional Research Program.
BUREAU NO BR-1-A-025-PR
PUB DATE Sep 72
GRANT OEG-1-71-0016(509)
NOTE 12p.; Not available in hard copy due to marginal legibility of original document

EDRS PRICE MF-$0.75 HC Not Available from EDRS. PLUS POSTAGE
DESCRIPTORS Electronic Equipment; *Information Processing; Research Methodology; Sensory Integration; *Time Factors (Learning); Visual Acuity; *Visual Discrimination; *Visual Stimuli; Word Recognition

ABSTRACT

Two important processes in the acquisition of visually presented information are the ability to maintain discrete perceptual events as separate in time and the ability to abstract information from brief exposures. Five phenomena were measured which appear to reflect these abilities. Critical Flicker Frequency (CFF) is the intermittency rate at which flashes of light fuse to yield the visual sensation of continuous light. Temporal Numerosity is a measure obtained when a specific number of flashes are exposed at a given rate and the number reported is compared with the number presented. Spatial Numerosity involves estimates of the number of dots in a briefly exposed pattern. Word Recognition involves recognizing five letter words that are briefly exposed. Temporal Integration involves presenting two halves of words or pictures in succession. The task is to combine them into a unitary whole. Eleven subjects were tested. Some subjects were consistently superior, others inferior, on these tasks. Some showed inconsistent results. Two correlations were significant at the .05 level: CFF versus Temporal Integration (rho .70) and Temporal Integration versus Temporal Numerosity (rho .63). All others were insignificant. It was suggested that CFF, Temporal Numerosity and Temporal Integration be investigated in relation to reading skills. (Author)

ED100978

Final Report

Project No. 1-A-025
Grant No. OEG-1-71-0016 (509)

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THE ACQUISITION OF VISUAL INFORMATION

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September 1972

The research reported herin was performed pursuant to a grant with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

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INTRODUCTION. The extent to which visually presented information can be successfully acquired by a subject depends upon the precision of basic time-dependent functions of the central nervous system. One such function is the ability to maintain perceptual events as separate in time. Measuring this temporal acuity function for visual input has been approached by several investigators using a variety of stimulus materials and experimental procedures. Often the investigator has been interested, not in evaluating temporal acuity as such, but in using some procedure that implies a temporal acuity function in the study of related processes.

The present study concentrates on measuring several different phenomena some of which involve this ability to maintain perceptual separation of visual stimuli presented at separate times. Other phenomena measured involve the subject's capacity to extract information from brief visual presentations.

A survey of related literature was conducted prior to the present investigation in order to identify appropriate phenomena that reflect these basic abilities. The general approach taken was to measure several such phenomena for the same subjects in the same experimental situation. The emphasis in this initial study was to be on developing appropriate apparatus and procedures for use in later, more extensive investigations. It was also hoped that preliminary indications would be obtained of general interrelationships among the phenomena and that this would suggest which of the phenomena measured a single underlying perceptual process and which measured different processes.

The following phenomena were chosen as appropriate:

A. Critical Flicker Frequency. Critical Flicker Frequency (CFF), (also known as critical fusion frequency and flicker fusion frequency), refers to the intermittency rate at which a long train of temporally separate photic flashes fuse perceptually to yield the same visual sensation as continuous photic stimulation. CFF can thus be viewed as a measure of visual-temporal acuity in that when the interstimulus interval is sufficiently short the discrimination of individual flashes breaks down. This ability to maintain the perception of individual flashes is often considered to be an indication of the precision of this aspect of nervous system functioning.

The history of research on CFF is extensive. An annotated bibliography covering the period from 1740 to 1952 cites about 1200 references[1]. Since that date CFF has maintained its popularity as a research topic so that several hundred additional studies have been conducted. Although many inconsistencies and unresolved problems remain, a number of general factors have been shown to reduce

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CFF. These include fatigue, anoxia, old age, various depressant drugs, and other conditions that lower central nervous system effectiveness. CFF, then, reflects to some extent the temporal efficiency of the central nervous system.

There is an intermediate transition stage before clear fusion is reached during which some flicker still remains. During this stage some flashes are perceived and others are not perceived.

B. Temporal Numerosity. A technique used to investigate this transition stage is to employ, not a long continuous series of flashes, but to utilize a short train of pulses for which the number of individual stimuli can be carefully controlled. In this manner it is possible to evaluate how many flashes out of a specific train are reported and how many are perceptually lost. Such studies are said to investigate the temporal numerosity function since the subject's report is concerned with the number of flashes perceived. Such studies have been taken as evidence for a quantum unit of psychological duration or a 'psychological moment'[2]. Some investigators have identified the alpha rhythm of the electroencephalogram as indicating a 'scanning mechanism' having such a quantizing function. Others reject this hypothesis and prefer to refer to a cortical excitability cycle which serves as a gating mechanism[3].

C. Spatial Numerosity. The term 'numerosity' is also applied in investigations where an array of stimuli, usually dots, are exposed for a short, controlled duration. The task of the subject is to estimate the number of dots presented. Such studies are termed investigations of 'spatial numerosity' and have usually been interpreted in relation to information processing models of cognitive mechanisms[4].

D. Word Recognition. In addition to temporal and spatial numerosity, other types of experiments have employed brief exposures of visual stimuli. The general assumption that underlies many such studies is that the stimulus situation is 'impoverished' by the short exposure duration. Perception is assumed to be a time-based process such that restricted exposure reduces the amount of information that can be extracted from the stimulus presentation. Quantification of how much information can be obtained from a single brief exposure is a problem that dates back to the earliest days of experimental psychology. In more recent years, two general approaches have been taken to this problem. One, termed 'microgenetic theory' by Flavell and Draguns[5], attempts to describe stages of increasing clarity and differentiation that a visual percept undergoes with successively longer presentation times. The second approach, the information theory approach, attempts to identify qualitatively different

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processing operations at different stages[6].

Some studies have employed nonsense or 'random' forms[7]. In other instances, meaningful symbols or pictures have been used. The exposure of symbols, such as words, would seem to tap association processes at a different level from those involved in such a task as estimating the number of sides of a complex figure. For the purpose of the present study, it was decided to employ a tachistoscopic word recognition task because of the possible relevance of this investigation to the reading process.

E. Spatial-Temporal Integration. The consolidation of temporally discrete visual stimuli may be constructive or destructive in relation to a given perceptual end result. In CFF or temporal numerosity, the fusion of stimuli results in a loss of visual information. If, however, the stimuli are spatially and temporally separate but each can contribute to a meaningful combination, this adds to the information available to the subject. For this reason it was decided to include a task to test the subjects' ability to integrate information from temporally separate stimulus presentations into a single meaningful whole.

To summarize, the present study was designed to obtain measures of five time-dependent phenomena on the same subjects. These were: A. CFF; B. Temporal Numerosity; C. Spatial Numerosity; D. Word Recognition, and, E. Spatial-Temporal Integration. The general aims of the study were: 1. to develop and test electronic and optical equipment appropriate for measuring each type of perceptual phenomenon. 2. to develop stimulus materials and testing procedures appropriate for each measurement situation, and, 3. to conduct a preliminary experiment to test out the apparatus and procedure and to obtain preliminary data.

METHODS. A. Apparatus. The basic apparatus consisted of a 2-channel projection tachistoscope with associated time interval generators. This same apparatus was employed in all measurements with the exception of CFF. Because of response time limitations of the electronic shutters, it was found necessary to use an auxilliary electronic stroboscope to produce appropriate stimuli for CFF measurements. The lamp housing of the stroboscope was covered with opaque black paper except for a .6 cmcircular opening at the center which constituted the stimulus area. Since this display was located 50 cm from the subject, it constituted a foveal stimulus.

The tachistoscope employed two Kodak Carrousel 800 projectors, two electronic shutters with associated shutter drivers, and a 4-channel electronic timer. Figure 1 at the top of the following page is a diagram of the apparatus arrangement.

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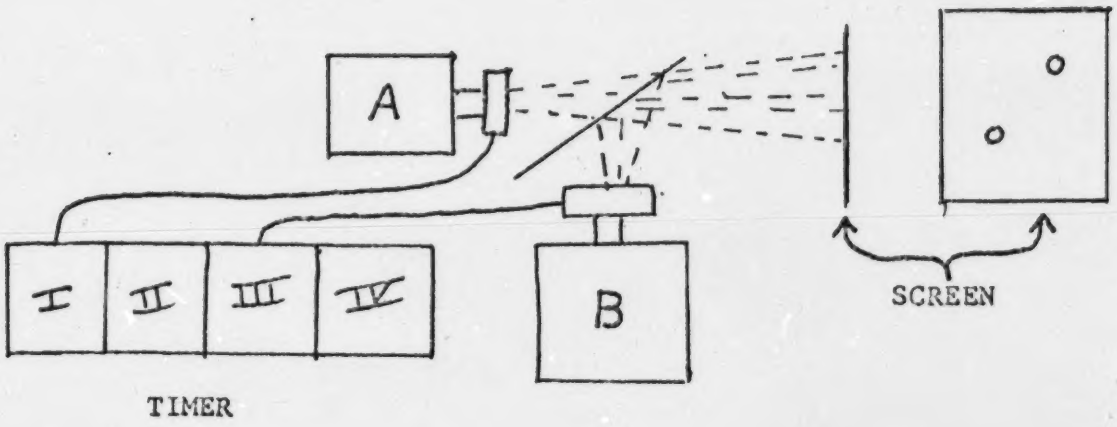

Figure 1. Arrangement of Equipment.

A and B represent the projectors with attached electronic shutters. Images from both projectors are presented onto the same screen by the beam splitter. The timer generates four independently adjustable intervals. Start/end switches for Channels II, III and IV allow these channels to start at the onset or offset of the preceding channel. A cycle/normal switch provides further flexibility. In the cycle mode the timer will repeat the timing sequence until the operation is terminated by the start/stop control. In the normal mode, the timer executes a single sequence.

To further improve flexibility, an auxilliary switching arrangement has been designed for the timer. When this switch is activated, Channel IV controls the total duration over which the other channels are permitted to cycle. Thus if one complete cycle for Channels I, II and III totals 100 milliseconds and Channel IV is set at 500 milliseconds; the timer will operate through five cycles then stop. Any predetermined number of stimulus exposures, such as required in measuring temporal numerosity, can thus be programmed.

Subjects, Procedures and Test Materials. Eleven subjects (six male and five female) were tested. All were students or faculty members at Massachusetts College of Optometry and ranged in age from 21 to 38 years. All had visual acuity, with or without correction, of 20/25 or better. All tests were conducted in a room lighted at a photopic level (18 ft.C.) to minimize complications of light adaptation. The subjects were located one meter directly in front of the translucent back-projection screen.

A. CFF. Four measures were taken in ABBA order. Thus the first measure began with the flicker distinctly below fusion. The subject increased the intermittency rate until fusion was reached. The second and third measures were descending trials and the fourth measure repeated the procedure of the first measure. These four measures were averaged to yield the index used in later computations. Because high CFF

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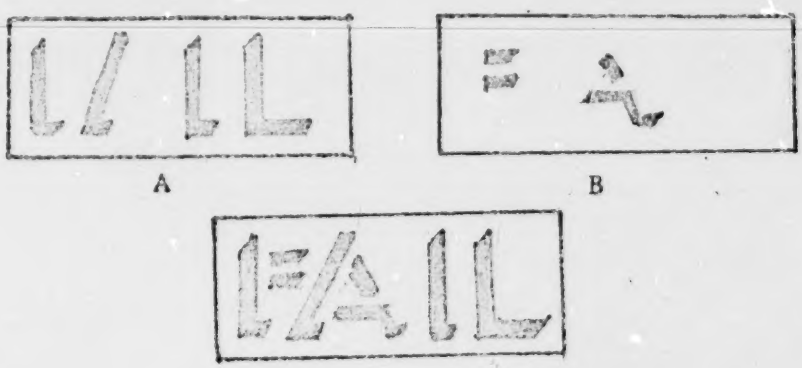
indicates superior discriminability, the highest CFF was assigned a rank of 1 in later computations.

B. Word Recognition. The second measure taken was word recognition under tachistoscopic exposure. Ten five-letter words were exposed for .025 second each. The words were: churl, plank, hinge, token, knife, means, paper, scale, habit and white. The score was the total number of letters wrong or omitted. For the purpose of computing subject ranks, the smallest number of errors was assigned a rank of 1.

C. Spatial Numerosity. Six stimulus slides were exposed for .01 seconds each. After each exposure the subject estimated the number of dots in the array. An error score was obtained; with fewest errors assigned a rank of 1.

D. Temporal Numerosity. A rectangular red stimulus, 2 cm by 3 cm, was repeated at the same visual location in the center of the display screen. Twelve trials were run, consisting of six stimulus trains, repeated in reverse order. The measure taken was total errors, with fewest errors assigned a rank of 1.

E. Spatial-Temporal Integration. Two types of stimulus materials were used. The first involved 'fractured words'; that is, words so divided that neither half appeared meaningfull in itself but when presented together the word became apparent. The second type involved outline drawings of animals such that both halves were required for appropriate perception. Examples are shown in Figures 2 and 3.



A B C

Figure 2. The 'Fractured Word' FAIL.

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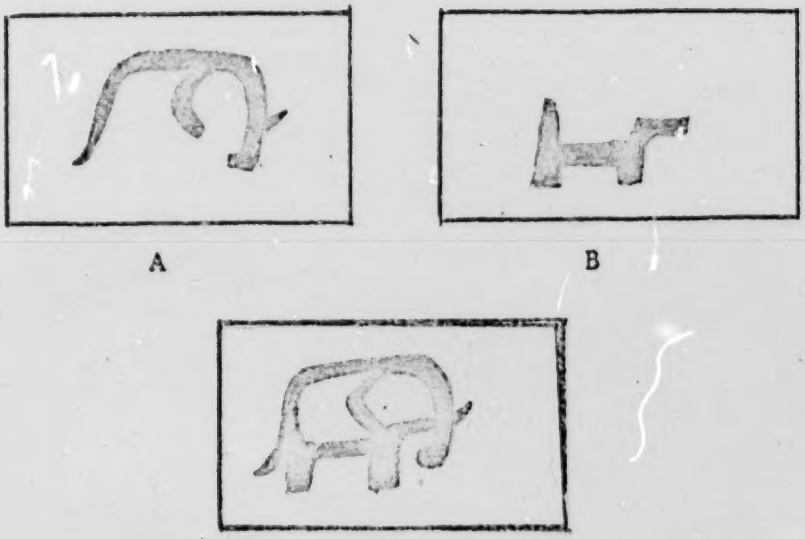

A B C

Figure 3. The 'Fractured Animal' ELEPHANT.

A and B of Figure 2 show the two halves of the fractured word FAIL and C shows the result when the halves are properly integrated to form the complete word. In the same way, for Figure 3 A and B are halves of the outline of an elephant and C illustrates the complete figure.

The interstimulus interval for the halves was varied during the course of each trial. The duration of each half was 200 milliseconds with the duration or extent of overlap regulated by exposing the second half at some controlled interval after the start of the first half. The initial presentation was with 50 milliseconds of separation between the termination of the first exposure and the beginning of the second exposure. The second presentation was such that termination of the first exposure (half 'A') coincided with the beginning of the second exposure (half 'B'). With additional presentations, the overlap of the two exposures was increased in 10 millisecond steps.

Two responses were required on each trial. The first was to identify the word or animal correctly. Second was to report when the two halves appeared in such a manner that the complete word or picture was perceived as present simultaneously. Since the two reports were closely related, only the second was used in computations. A rank of 1 was assigned to the least amount of temporal overlap that was reported as appearing simultaneous.

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RESULTS. The principal results are summarized below. Interpretation of results is presented in the 'Conclusions" section.

Subject #	CFF	S.N.	T.N.	T.I.	W.R.	Ave. Rank
1	53 (8)	10 (11)	21 (9)	28 (11)	22 (8.5)	9.5
2	64 (1)	6 (4)	5 (1)	86 (2)	9 (2.5)	2.3
3	52 (9)	7 (8)	22 (10)	66 (5)	36 (11)	8.6
4	58 (4)	7 (8)	33 (11)	58 (6)	17 (7)	7.2
5	62 (2)	7 (8)	9 (2.5)	96 (1)	16 (6)	3.7
6.	61 (3)	7 (8)	9 (2.5)	67 (4)	9 (2.5)	4.0
7	47 (11)	5 (1.5)	10 (4.5)	50 (8.5)	22 (8.5)	6.8
8	54 (7)	6 (4)	10 (4.5)	83 (3)	26 (10)	5.7
9	57 (5)	5 (1.5)	12 (7)	57 (7)	10 (4)	4.9
10	56 (6)	6 (4)	17 (8)	38 (10)	4 (1)	5.8
11	51 (10)	7 (8)	11 (6)	50 (8.5)	14 (5)	7.7

Table 1. Summarized data for the 11 subjects on the five measures. The first number in each column is the subject's score. The number in parentheses is the rank order. CFF is Critical Flicker Frequency. S.N. is Spatial Numerosity. T.N. is Temporal Numerosity. T.I. is Temporal-Spatial Integration. W.R. is Word Recognition.

	W.R.	T.I.	T.N.	S.N.
CFF	.57	.70	.44	.02
S.N.	.27	.10	.33	
T.N.	.41	.63		
T.I.	.03			

Table 2. Intercorrelations (based on Spearman rank order) of the five measures. Abbreviations as listed for Table 1.

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CONCLUSIONS. Although the data are preliminary and limited by the small number of subjects tested, they are suggestive in several ways. The average rank column of Table 1 shows ranks varying from 2.3 to 9.5, where 5.5 is the overall mean rank. This would appear to indicate that some subjects tend to score consistently better overall on tests such as employed here than other subjects. This may indicate a general superiority of temporally-based information acquisition for such subjects. It would seem to be worthwhile to devote further research attention to the analysis of such individual differences.

The small number of subjects makes interpretation of the data tentative but the rank-order intercorrelations are highly suggestive. With only eleven subjects, a rank order correlation of .60 is required for significance at the .05 level. .74 is required at the .01 level. It can be seen that no correlation reached the .01 level and only two (CFF-Temporal Integration and Temporal Numerosity-Temporal Integration) reached the .05 level. It is interesting to note that these phenomena (CFF, Temporal Integration and Temporal Numerosity) can all be considered as temporal acuity functions. In each case they involve correctly discriminating the temporal separation, or lack of it, of successive stimuli. Spatial Numerosity and Word Recognition, on the other hand, which showed smaller correlations with each other and with the other measures, involve abstracting information from single stimulus presentations.

Further investigation involving factor analytic evaluation methods and increased sample size should resolve any questions of the reliability of these preliminary data.

As an initial exploration, this experiment has concentrated largely on developing flexible multi-purpose apparatus and testing out measurement procedures rather than the acquisition of data. It has been successful in these aims in that the apparatus performed with a high degree of reliability and the stimulus materials and procedures appeared well-suited to the tasks. The 'fractured words' and 'fractured pictures' technique shows special promise as a procedure which may prove valuable in further experimentation relating to temporal integration. It is important that such investigations be undertaken since the integration or consolidation of information presented over time is crucial to information processing and hence to such tasks as reading.

Although the present study does not deal directly with reading disabilities, it does have relevance to those problems. The achievement of reading skills requires the acquisition, processing, storage and retrieval of visually-presented information. Unless fundamental processes in information acquisition are effective, the subsequent stages cannot be performed properly. Phenomena measured in this study -- particularly

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CFF, Temporal Numerosity, and Temporal Integration -- offer promise as indicies of the effectiveness of initial information acquisition. Further, more extensive, investigations are needed to evaluate the utility of such measures for possible use as diagnostic procedures related to reading and other visual-perceptual tasks.

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